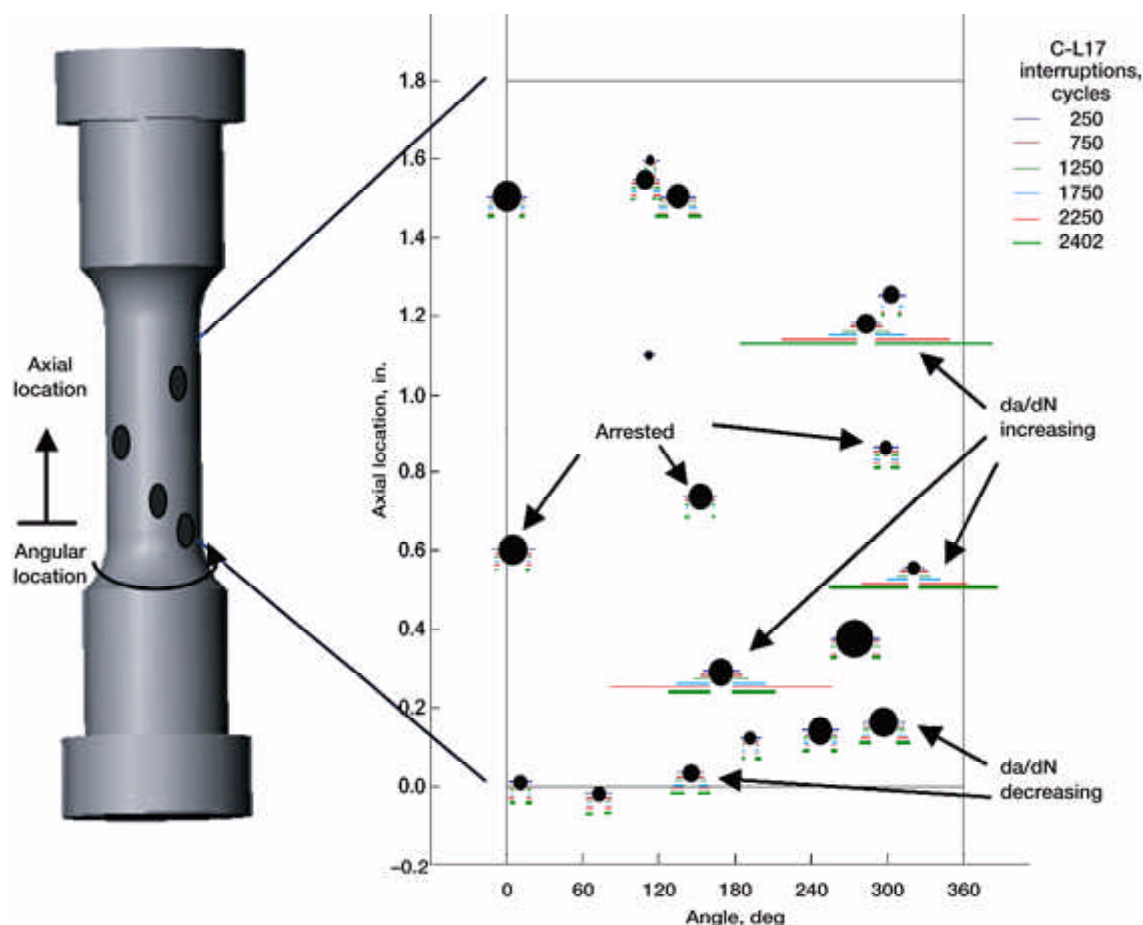


# Distribution of Inclusion-Initiated Fatigue Cracking in Powder Metallurgy Udimet 720 Characterized

In the absence of extrinsic surface damage, the fatigue life of metals is often dictated by the distribution of intrinsic defects. In powder metallurgy (PM) alloys, relatively large defects occur rarely enough that a typical characterization with a limited number of small-volume fatigue test specimens will not adequately sample inclusion-initiated damage. Counterintuitively, inclusion-initiated failure has a greater impact on the distribution in PM alloy fatigue lives because they tend to have fewer defects than their cast and wrought counterparts. Although the relative paucity of defects in PM alloys leads to higher mean fatigue lives, the distribution in observed lives tends to be broader. In order to study this important failure initiation mechanism without expending an inordinate number of specimens, a study was undertaken at the NASA Glenn Research Center where known populations of artificial inclusions (seeds) were introduced to production powder.

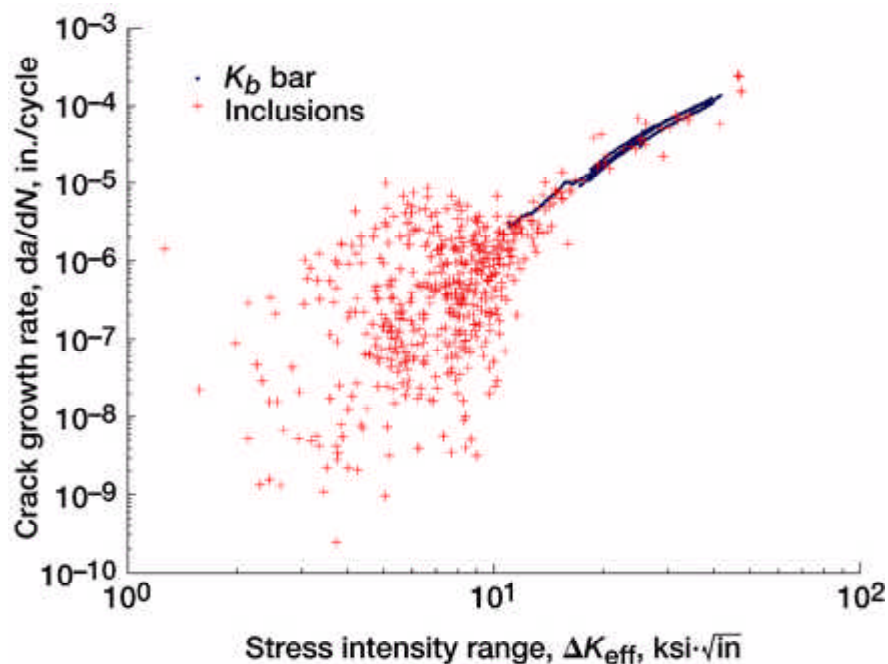


*Map of a low-cycle fatigue (LCF) specimen surface showing the relative sizes of observed surface inclusions and crack lengths observed at intervals during interrupted fatigue*

*testing;  $da/dN$ , crack growth rate.*

Long description. Illustration of surface specimen and graph of axial location in inches versus angle in degrees for C-L17 interruptions from 250 to 2402 cycles.

Fatigue specimens were machined from forgings produced from the seeded powder. Considerable effort has been expended in characterizing the crack growth rate from inclusion-initiated cracks in seeded PM alloys. A rotating and translating positioning system, with associated software, was devised to map the surface inclusions in low-cycle fatigue (LCF) test bars and to monitor the crack growth from these inclusions. The preceding graph illustrates the measured extension in fatigue cracks from inclusions on a seeded LCF test bar subjected to cyclic loading at a strain range of 0.8 percent and a strain ratio ( $\sigma_{\max}/\sigma_{\min}$ ) of zero. Notice that the observed inclusions fall into three categories: some do not propagate at all (arrest), some propagate with a decreasing crack growth rate, and a few propagate at increasing rates that can be modeled by fracture mechanics. The following graph shows the measured inclusion-initiated crack growth rates from 10 interrupted LCF tests plotted against stress intensities calculated for semielliptical cracks with the observed surface lengths. The expected scatter in the crack growth rates for stress intensity ranges near threshold is observed. These data will be used to help determine the distribution in growth rates of cracks emanating from inclusions as well as the proportion of cracks that arrest under various loading conditions.



*Distribution of measured growth rates of inclusion-initiated cracks in seeded Udimet 720 LCF test bars.  $K_b$  bar data represent large-crack propagation behavior.*

Long description. Graph of crack growth rate in inches per cycle versus stress intensity range in kips per square inch times the square root of inches, showing  $k_b$  bar data and inclusions.

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**Glenn contacts:** Jack Telesman, 216-433-3310, Ignacy.Telesman-1@nasa.gov; and Tim Gabb, 216-433-3272, Timothy.P.Gabb@nasa.gov

**U.S. Army Research Laboratory, Vehicle Technology Directorate at Glenn contacts:** Pete Bonacuse, 216-433-3309, Peter.J.Bonacuse@grc.nasa.gov; and Robert Barrie, 216-433-5090, Robert.L.Barrie@grc.nasa.gov

**Ohio Aerospace Institute (OAI) contacts:** Pete Kantzos, 216-433-5202, Pete.T.Kantzoz@grc.nasa.gov; and Louis J. Ghosn, 216-433-3822, Louis.J.Ghosn@grc.nasa.gov

**Authors:** Peter J. Bonacuse, Dr. Pete T. Kantzos, Robert L. Barrie, Dr. Jack Telesman, Dr. Louis J. Ghosn, and Dr. Tim P. Gabb

**Headquarters program office:** OAT

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